Section 19 Contents

Groundwater

19.1 Introduction

The Beryl-Enterprise area is one of the few parts of the state where groundwater mining (long-term overdraft beyond that necessary to develop the groundwater reservoir) is a current method of operation. This is because of the very large and easily tapped groundwater reserves and the absence of conflicting surface water rights.

The Cedar-Beaver Basin consists of five major structural basins containing unconsolidated deposits which form the primary aquifers. These are Beaver Valley, Milford Valley of the Escalante Desert (lower Beaver River), Parowan Valley, Cedar Valley and the Beryl-Enterprise area of the Escalante Desert. These are shown on Figure 19-1. The groundwater reservoir in the Sulfurdale area is not discussed in this report.

The alluvial fill in each of these basins essentially forms an isolated groundwater reservoir. There is very little subsurface water movement between the groundwater reservoirs. Also see Subsection 5.4.2.

19.2 Groundwater Budget

The groundwater budget for the Cedar/Beaver Basin is summarized in Table 19-1. Basinwide, there is an estimated 38 million acre-feet of recoverable water in storage, although the quality varies within each basin as well as from basin to basin.

Withdrawals from wells are more than half of the total groundwater basin discharge. The annual withdrawals are less than one-half percent of the estimated recoverable reserves. Groundwater data are available in digital form from the U.S. Geological Survey. Data on withdrawals from wells, published annually in *Groundwater Conditions in Utah*[18], are summarized in Table 19-2. These data do not include the recent non-consumptive withdrawal and re-injection of water at the Roosevelt geothermal station and Sulfurdale and the Escalante silver mine. Data on discharge, recharge and recoverable reserves are from various published reports, as noted. Most were published in the 1970s during the peak years of groundwater pumping and may exaggerate the basin overdraft compared to 1993 data.

"Recoverable Reserves" indicates the amount of water which could reasonably be extracted with present technology if society were willing to stand the social, economic, and environmental consequences. The "safe yield" (Section 5.3.3) of each basin depends on local aquifer and environmental conditions and is substantially less than the recoverable reserves.

There are substantial hydrologic differences between the individual groundwater reservoirs. These are

■ The Cedar/Beaver Basin depends more on groundwater than any other basin in Utah. Large scale groundwater development for irrigated agriculture has been practiced since the early 1900s.

Figure 19-1
PRIMARY GROUNDWATER RESERVOIRS SHOWING WELL CONCENTRATIONS
Cedar/Beaver Basin

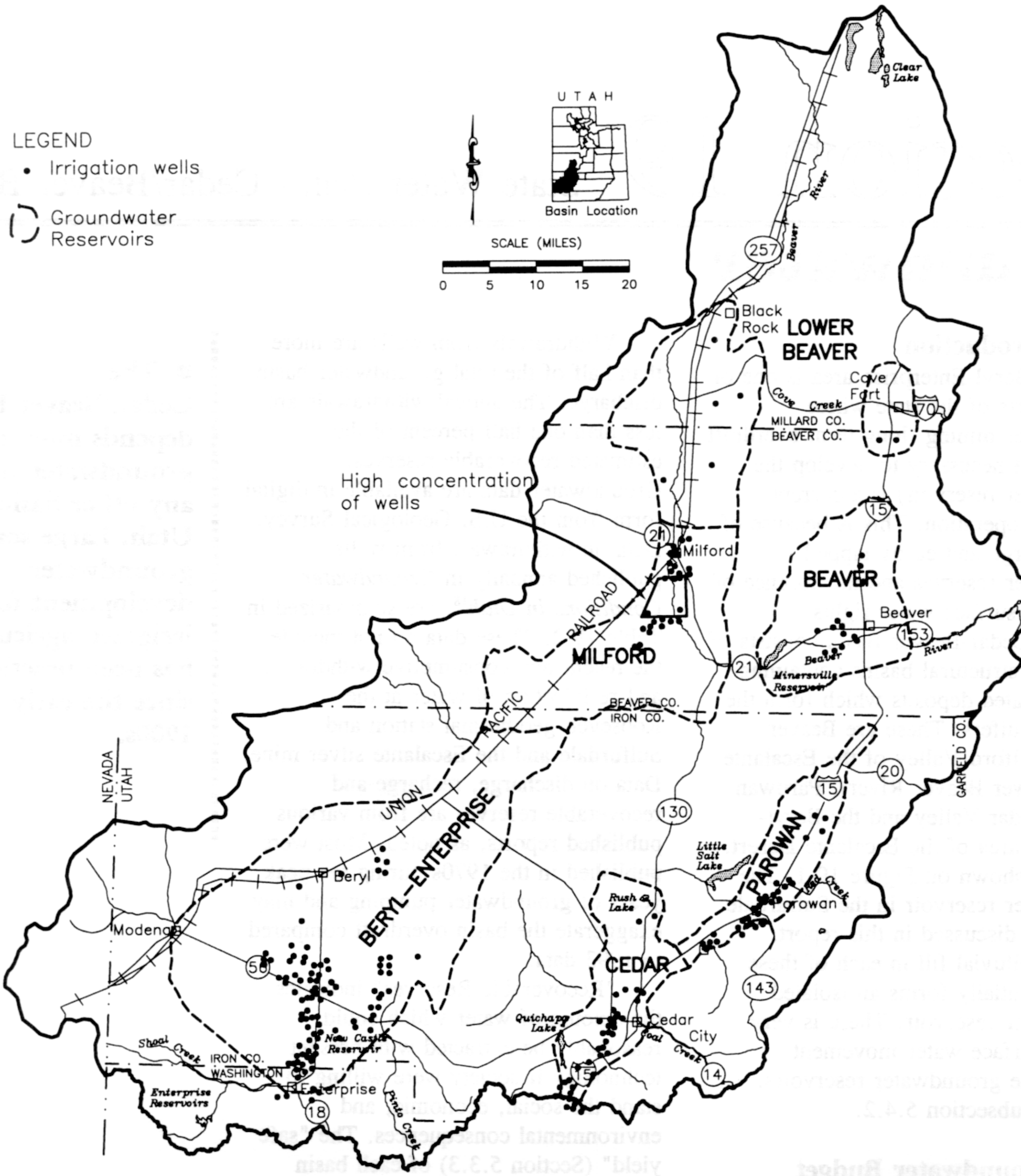


Table 19-1
GROUNDWATER BUDGET AND CHEMICAL QUALITY

Basin Name	Annual Discharge (1000 Ac.ft)	Annual Recharge (1000 Ac.ft)	Annual Withdrawals from wells[a] (1000 Ac.ft.)	Recoverable Reserves (1000 Ac.ft.)	Chemical Quality	Date Basin Closed to Approptn.
Beaver	56.2[d]	55.6[d]	7.3	4,000	Good[b]	1971
Milford	81.0[e]	58.2[e]	39.7	10,000	Good[b]	1956
Parowan	43.0[f]	40.0[f]	26.3	4,000	Good[c]	1971
Cedar	44.0[f]	40.0[f]	26.3	4,000	Good[c]	1966
Beryl-Enterprise	88.0[g]	48.1[g]	76.3	16,000	Good[b]	1956
TOTAL	312.2	241.9	175.9	38,000		

[a] 10-year average, March, 1984-March, 1994, Table 19-2.
[b] Contains some local areas of lower quality.
[c] Small areas of high sodium chloride concentration associated with playas in undrained depressions.
[d] Based on measurements made in 1974; ref. 8.
[e] Estimated for 1970-71; ref. 10.
[f] Estimated for 1974; ref. 2.
[g] Estimated for 1977; ref. 9.

Note: The annual withdrawals are included in the annual discharge.

Table 19-2
CEDAR/BEAVER BASIN GROUNDWATER PUMPAGE

(1000 Acre-feet)

Year	Beaver[a]	Milford[b]	Parowan	Cedar	Beryl[c]
1930					
1931		10.86			
1932		13.72			
1933		12.56			
1934		13.60			
1935		15.82			
1936		14.81			
1937		14.56			2.94
1938		10.13	5.05	10.00	
1939		13.34	6.00	11.90	
1940		18.00	6.03	12.40	2.57
1941		15.12			
1942		13.13			
1943		18.00			
1944		16.64			
1945		18.77	9.27	13.26	5.83
1946		20.45	9.58	16.14	16.62
1947		22.76	9.33	13.73	20.90
1948		21.06	9.53	14.20	33.49
1949		22.76	9.82	13.41	38.45
1950		30.89	10.04	16.63	51.32
1951		33.68	11.32	17.75	45.02
1952		33.09	10.61	11.48	46.99
1953		41.53	11.46	15.41	50.05
1954		39.92	12.50	16.80	54.30
1955		40.86	13.20	16.70	51.30
1956		43.77	15.40	17.90	60.10
1957		41.03	13.00	13.90	56.20
1958	6.00	38.53	12.60	13.04	50.40
1959	6.00	42.98	13.30	18.70	57.20
1960	6.00	48.30	14.30	17.80	65.10
1961	6.00	41.46	11.00	15.30	59.00
1962	6.00	42.96	12.00	19.00	62.00
1963	6.15	42.45	14.00	22.00	64.00
1964	6.10	45.81	16.00	22.00	72.00
1965	4.40	45.51	15.00	16.00	70.00
1966	5.80	51.69	19.60	24.80	78.90
1967	6.20	46.21	17.60	25.80	71.40
1968	7.20	49.07	21.60	29.60	74.20
1969	6.90	53.21	20.30	27.20	84.00
1970	8.30	56.50	25.60	31.40	70.00
1971	7.90	57.71	24.10	35.70	74.90

Table 19-2 (Continued)
CEDAR/BEAVER BASIN GROUNDWATER PUMPAGE

Year	Beaver[a]	Milford[b]	Parowan	Cedar	Beryl[c]
1972	8.90	59.30	28.00	34.90	77.10
1973	8.30	51.60	25.60	26.80	74.00
1974	10.00	70.20	30.70	42.30	93.40
1975	8.00	60.00	28.00	28.00	85.00
1976	11.50	65.00	34.00	37.00	79.00
1977	12.30	65.00	33.00	38.80	81.00
1978	12.00	58.00	29.00	31.00	71.00
1979	11.40	49.00	30.00	32.00	79.00
1980	10.10	61.00	28.00	28.00	71.00
1981	11.10	69.00	27.00	29.00	76.20
1982	9.80	55.00	25.00	28.00	80.80
1983	8.20	38.80	22.00	21.00	67.80
1984	7.10	32.20	22.00	20.00	66.70
1985	7.20	43.70	25.00	23.00	81.40
1986	7.00	37.70	23.10	19.00	73.40
1987	6.80	37.50	22.00	21.00	73.90
1988	7.00	33.95	20.00	20.00	68.50
1989	7.50	40.00	29.00	28.50	85.00
1990	7.50	42.40	31.00	30.00	86.00
1991	7.40	48.40	32.00	34.00	78.40
1992	7.90	36.40	30.60	34.00	72.00
1993	7.10	44.40	28.00	33.00	78.00
Averages[d]					
5-Year	7.48	42.32	30.12	31.90	79.88
10-Year	7.25	39.67	26.27	26.25	76.33
15-Year	8.21	44.63	26.31	26.70	75.87
20-Year	8.85	49.38	27.47	28.88	77.38
25-Year	8.69	50.64	26.92	29.34	77.10
30-Year	8.23	50.14	25.43	28.39	76.47

[a] Records Prior to 1958. The 1958-1962 & 1967-1973 pumpage was estimated.
[b] Does not include the 1985-1993 approximately 6,000 ac-ft per year pumped for geothermal power production and then reinjected as there is zero loss.
[c] Does not include the 1981-1988 approximately 20,300 ac-ft per year pumped to dewater a mine and then spread nearby for recharge as there was zero loss.
[d] Calculated from 1993 back in time.
Note: Pumping for geothermal power production at Sulphurdale is not included.

outlined in the following sections. The water-related terms are defined in Section A.

19.2.1 Beaver Valley[45]

The principal groundwater reservoir of Beaver Valley consists of unconsolidated basin fill which has been divided into three units. The Sevier River Formation of Tertiary age consists of unconsolidated to partly consolidated deposits of sand, gravel, silt and clay of alluvial and lacustrine origin. Overlying the Sevier River formation in the central part of the valley are younger and older alluvial units of Quaternary age. All units are lenticular in nature, with water-bearing gravel interbedded with less permeable layers of silt and clay.

Recharge - Of the 55,600 acre-feet of recharge to the groundwater reservoir, 39,000 acre-feet is by infiltration of excess water from irrigated fields and canals. The remainder comes from direct precipitation, streambed infiltration and subsurface inflow from bedrock.

Discharge - Because of the relatively large surface water supply, there has been less reliance on groundwater in Beaver Valley than in the rest of the basin. Roughly half the discharge from the groundwater reservoir (28,000 acre-feet) comes from springs. The remainder is from wells (10,000 acre-feet in 1974; 7,250 acre-feet from 1984 to 1994) and evapotranspiration (18,000). See Figure 19-2. About 300 acre-feet per year is believed to leave the valley as subsurface flow. Unconsumed spring discharge flows into Minersville Reservoir, from where it is released downstream to Milford Valley as surface flow.

Storage - The alluvial basin fill is believed to be 500 to 800 feet thick in the central part of the Beaver Valley. Assuming a specific yield of 0.20, about 4 million acre-feet of water is contained in the upper 200 feet of valley fill.

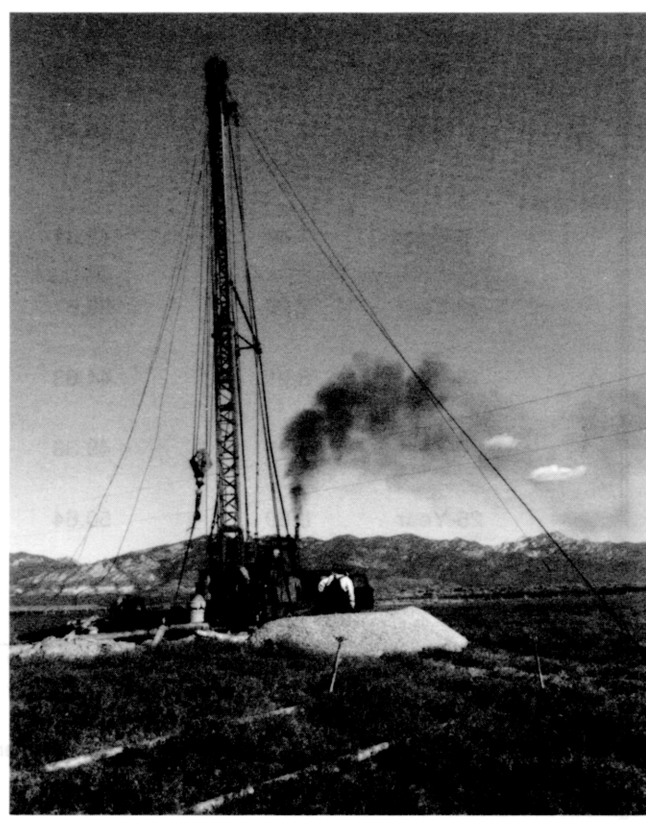
Change in Storage - The estimated discharge is within 1 percent of the estimated recharge, indicating there is little long-term change in groundwater storage. The hydrographs of pumped wells show a strong annual fluctuation, but little interannual change. Examination of well hydrographs show that groundwater levels are high in the summer and decline in the winter, responding more to infiltration of surface water than to groundwater pumping. The alluvial basin is therefore functioning more as a drainage system than a reservoir.

Water Quality - The quality of groundwater is generally good. Most samples contain 300 mg/l or less of TDS (total dissolved solids). Dissolved solids tend to increase toward the southwest end of the valley, and to increase with depth, being higher in the older, less permeable basin fill units. Groundwater quality is discussed further in Section 12. There appear to be no sources of brackish water which could cause long-term deterioration of quality by intrusion.

19.2.2 Milford Area[46]

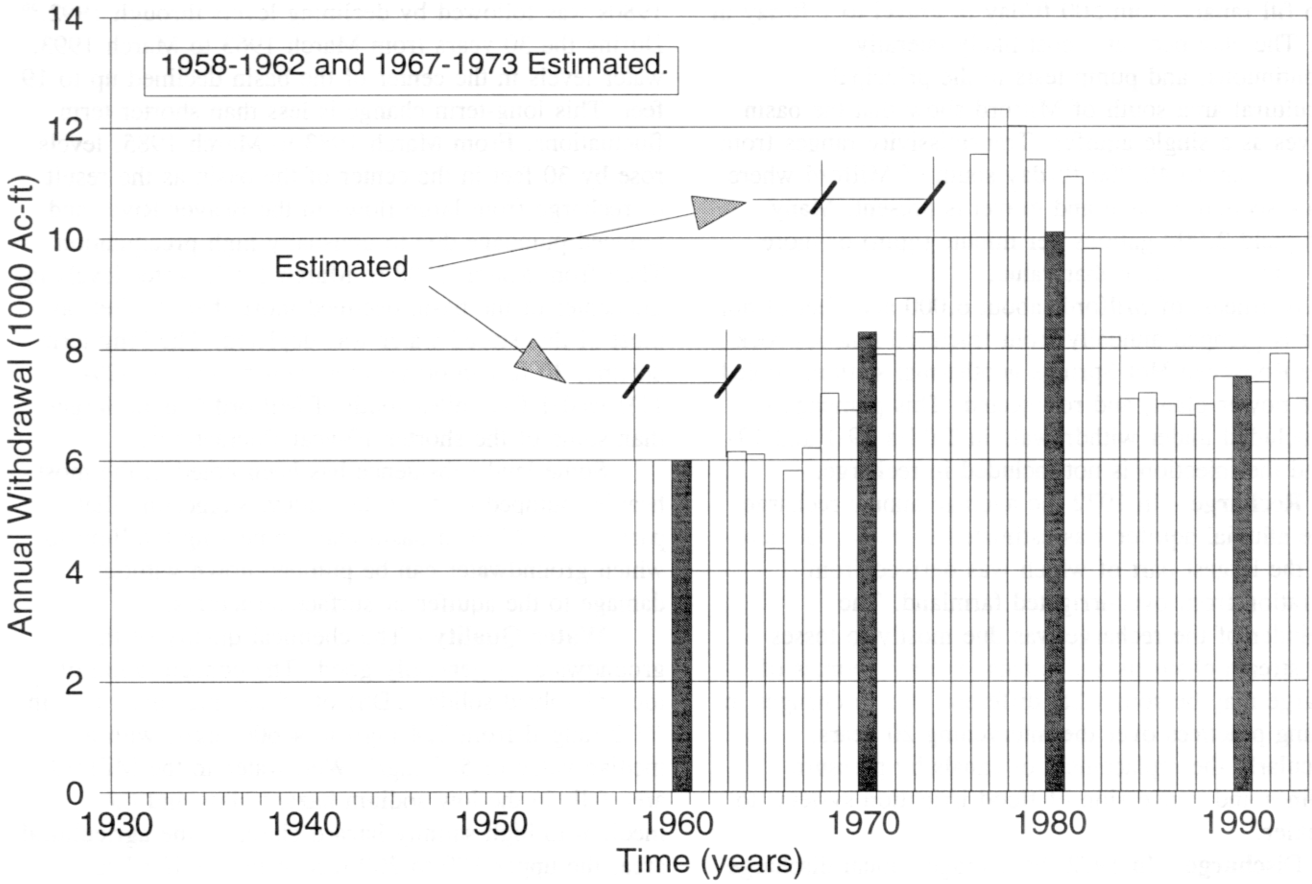
The Milford Valley groundwater basin extends from Rocky Ford Dam on the Beaver River downstream to where the Beaver River disappears in the Black Rock Desert. The alluvial basin underlying the Escalante Desert continues southward into the Beryl-Enterprise area; the Milford Valley is arbitrarily divided from the rest of the Escalante Desert at the narrow neck just south of the Beaver-Iron County line. Groundwater development for irrigation began early in this century and was well underway by the 1920s.[11]

The alluvial basin fill constitutes the primary groundwater reservoir, and consists of interbedded gravel, sand and clay. Little exploration has been conducted in bedrock, except for testing reserves in the Roosevelt Hot Springs geothermal area and a recent



Well drilling near Beaver

Figure 19-2
BEAVER VALLEY GROUNDWATER PUMPAGE



deep well at the Continental Lime Company plant on the east flank of the Cricket Mountains.

Measured hydraulic conductivity in the alluvial basin fill ranges from 500 ft/day in gravel to 1 ft/day in clay. The clay beds are most likely laterally discontinuous, and pump tests in the principal agricultural area south of Milford show that the basin behaves as a single aquifer. Transmissivity ranges from 1,000 ft^2/day to 40,000 ft^2/day south of Milford where a thick section of sand and gravel is present. Many wells yield 2,000 gallons per minute (gpm) or more with a few exceeding that value.

Northeast of Milford, about 6,000 acre-feet of hot water is pumped annually from fractured igneous rock at the Roosevelt Hot Springs geothermal station, cooled in the power plant, and re-injected. This pumpage is not included under withdrawals in Tables 19-1 and 19-2, and the injection is not included in recharge.

Recharge - In 1972 the average annual recharge to the alluvial aquifer was estimated to be 58,000 acre-feet, the largest part of which was derived from infiltration from over-irrigated farmland. The remainder of the recharge was due mostly to losses from stream channels and canals. Present sources of recharge may be somewhat different, due to changes in farming practices over the intervening 20 years, particularly the replacement of canals by pressure pipelines and conversion of flood irrigation systems to sprinkler.

Discharge - In 1972 the average annual discharge was estimated to be 81,000 acre feet, most of which was from pumpage of wells, which at that time was near the all-time peak of 59,300 acre-feet (Figure 19-3). The 10-year average pumpage from March of 1984 to March of 1994 was 45,000 acre-feet (Table 19-2), substantially less than 1972. Most of the remaining discharge (24,000 acre-feet) was attributed to evapotranspiration from 95,000 acres of "phreatophytes", which included but was not limited to riparian and wetland areas of the valley where the water table is shallow.

Subsurface outflow from the basin is negligible. Thermo Hot Spring, the one spring which rises within the alluvial basin, discharges about 100 acre-feet per year which is consumed locally by evapotranspiration.

Storage - In the center of the basin the alluvial fill is at least 1,000 feet thick. An estimated 10 million acre-feet of water could be recovered from storage from the upper 200 feet of the basin fill. This is more than 100 times the estimated annual discharge.

Change in Storage - Groundwater levels in the Milford area trended downward from 1950 to 1970, then leveled off in the 1970s. A sharp rise in the early 1980s was followed by declining levels through 1992.[56] During the 30 years from March 1963 to March 1993, water levels in the center of the basin declined up to 19 feet. This long-term change is less than shorter term fluctuations. From March 1983 to March 1985, levels rose by 30 feet in the center of the basin as the result of recharge from large flows in the Beaver River and reduced pumpage due to unusually high precipitation. Then from March 1988 to March 1993, water levels in the center of the basin declined more than 20 feet, as most of this stored water was depleted. The long term decline, 30 feet in 60 years at well number (C-29-11)13aad-1 five miles south of Milford,[56] is no larger than some of the shorter 10-year fluctuations.

Some land subsidence has been noted in the most heavily pumped parts of the valley, suggesting that parts of the Milford basin may be nearing the limit to which groundwater can be pumped down without damage to the aquifer or surface structures.

Water Quality - The chemical quality of the groundwater is generally good. The concentration of total dissolved solids (TDS) of 35 samples measured in 1972 ranged from 224 mg/l to 4,600 mg/l, with a median value of 569 mg/l. Well water in the Milford area falls in the low sodium hazard class and the medium to high salinity hazard class. In the agricultural area, the upper 100 to 200 feet of the aquifer has poorer quality due to the infiltration of excess irrigation water bearing dissolved minerals concentrated by evaporation, soil leachates, fertilizers and pesticides. Many wells show a long-term downward trend in water quality. This is probably due to the infiltration of excess irrigation water, but some may be due to the lateral intrusion of naturally occurring poor quality water. Cross contamination from poorly constructed wells is also a source of groundwater pollution. The 1962 map of groundwater quality, shows areas of brackish water along the west margin of the valley, both north and south of Milford, and near Thermo Hot Spring. Groundwater quality is discussed further in Section 12.

19.2.3 Parowan Valley[7]

Parowan Valley is a topographically closed basin with a low divide through which it has spilled toward Cedar Valley during wetter climates in the geological past. Since settlement, water has been known to flow through the Parowan Gap into Cedar Valley. Parowan

Figure 19-3
MILFORD VALLEY GROUNDWATER PUMPAGE

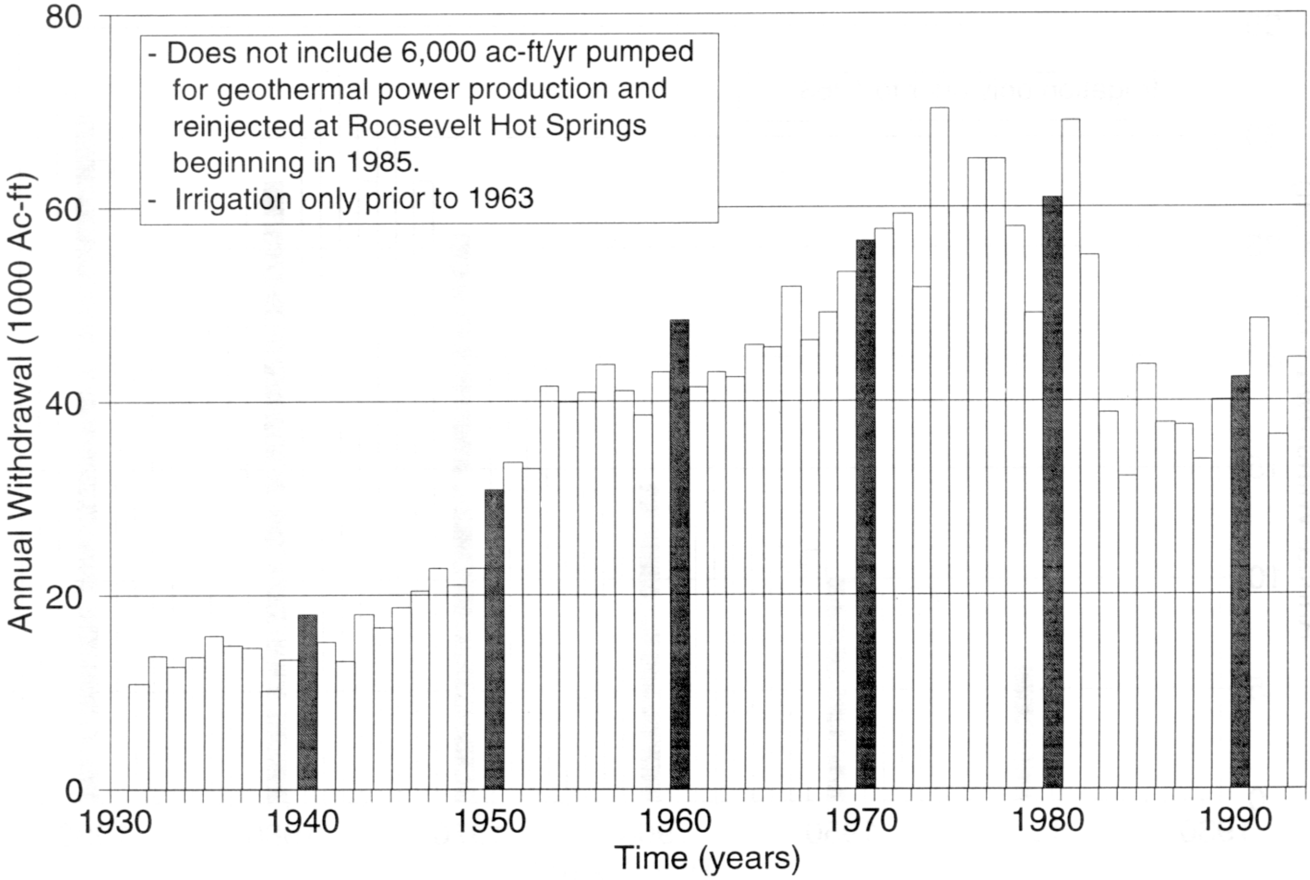
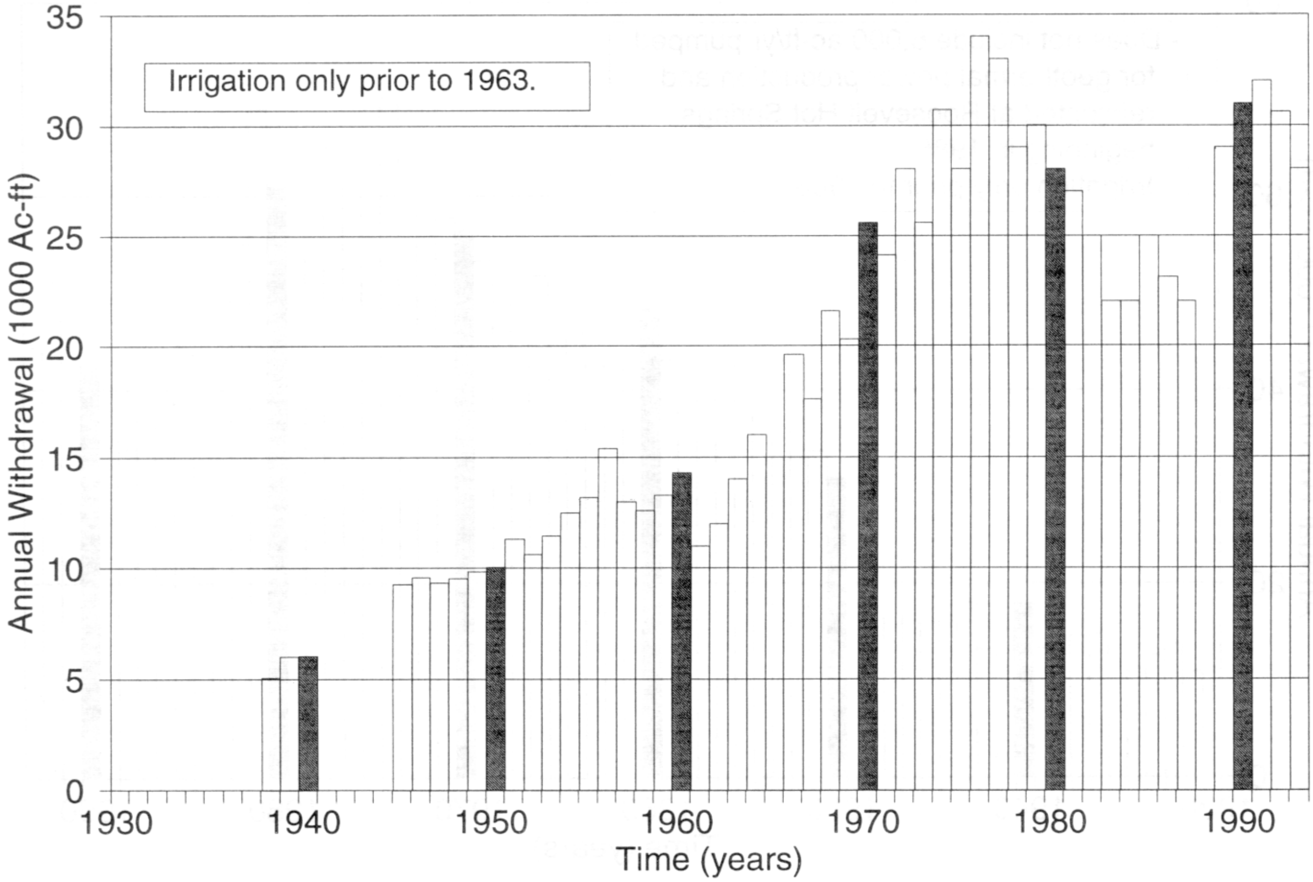


Figure 19-4
PAROWAN VALLEY GROUNDWATER PUMPAGE



Valley receives runoff from several perennial streams draining the Markagunt Plateau which recharge the groundwater system during wet years. The undrained bottom of the valley is occupied by Little Salt Lake, an ephemeral playa-lake.

The alluvial basin fill constitutes the groundwater aquifer, and consists of interbedded gravel, sand and clay, generally coarser near the edges of the basin and fining toward the center. Precipitated salt is found in the bed of Little Salt Lake, and locally basalt is interbedded with the alluvium. Consolidated sedimentary rocks around the basin margins yield water to springs, but little groundwater exploration has been conducted in the consolidated rock units.

Interbedded clay layers provide barriers to vertical movement of water in the central part of the valley creating perched and artesian conditions. The area of flowing wells had decreased from 46 square miles in 1940 to 36 square miles in 1974.

Recharge - Total annual recharge to the Parowan Valley groundwater basin is estimated to be 40,000 acre-feet. Most of this comes from stream infiltration into the gravelly deposits of alluvial fans at the mouths of canyons. Most of the remainder is infiltration of excess irrigation water. Some water may recharge the alluvial basins from the consolidated rock of the mountain blocks, but the quantity is unknown. Trans-basin inflow is believed to be negligible.

Discharge - Average annual discharge is estimated to be 43,000 acre-feet, more than half of which is from wells in the alluvial basin fill. About 12,000 acre-feet is estimated to be discharged from the groundwater system by evapotranspiration from salt grass meadows, other phreatophytes, and the bed of Little Salt Lake. The largest spring on the valley floor, Willow Spring, discharges about 40 gpm (65 acre-feet per year).

Groundwater pumpage increased steadily since records began in 1938 until the mid-1970s (Figure 19-4). Since then, pumping has fluctuated in a broad, decadal cycle, reflecting the wetter years in the early 1980s and the drought of the late 1980s. The 10-year average pumpage from March 1984 to March of 1994 was 26,300 acre-feet, which is not much different from the 30-year average.

Springs issuing from the consolidated rock in the mountains are the source of most of the culinary water in municipal systems. These also provide base flow in the streams.

Storage - The total water contained in the basin fill is estimated to be 20 million acre-feet. Approximately 20 percent, or 4 million acre-feet, are recoverable reserves (Table 19-1).

Change in Storage - During the 30 years from 1963 to 1993, water levels declined throughout Parowan valley where records are available. The area of greatest decline, more than 40 feet, is centered on the Parowan Creek alluvial fan at the town of Parowan.[37] The declines extend nearly to the edge of Little Salt Lake. Short term fluctuations have also been substantial. During wet years the pattern of change is similar, centered around the Parowan Creek and Summit Creek alluvial fans where most of the recharge takes place. From March 1983 to March 1985, water levels rose throughout the valley, with an increase of nearly 30 feet near Parowan.[18] The stored water was subsequently lost to continuing declines through 1992.[37] The hydrograph of well (C-34-8)5bca-1 near Paragonah[37] shows a declining water level from 1950 into the 1960s, then levelling off with fluctuations until 1985, then continuing a decline to the present. The observation well (C-34-10)24cbc-2 near Summit shows a more or less continuous decline of 45 feet from 1950 to the present.

The alluvial basin is providing carryover storage on a decade time scale. However, there is also a long-term (40-year) downward trend in groundwater levels which is continuing. The presence of artesian conditions in the center of the basin and the absence of land subsidence related to groundwater pumping suggests that groundwater overdraft is not yet a serious problem.

Water Quality - Water quality throughout the Parowan Valley is generally good. Even around the margins of Little Salt Lake TDS does not exceed 300 mg/l. There appears to have been little decrease in quality over the years. The playa salt pan of Little Salt Lake was probably generated over a long time by the evaporation of water, slowly seeping upward under artesian pressure from the confined aquifers at depth. As long as the aquifers remain pressurized, there is no potential for intrusion of brine from the lake. At the present time, the artesian pressure is seasonal; that is, most artesian wells flow only in the winter when irrigation wells are not being pumped. As groundwater levels continue to decline, the average pressure gradient at Little Salt Lake could be reversed and the lake may become a source of contamination.

19.2.4 Cedar Valley[7]

Cedar Valley is geologically similar to Parowan Valley, being a structural basin bounded by faults on the east, and probably on the west as well, and containing a thick section of unconsolidated alluvial basin fill. The principal surface stream is Coal Creek, which drains from the Markagunt Plateau to the east. Deposition of the large alluvial fan of Coal Creek has divided the valley topographically into two closed depressions; Quichapah Lake to the south and Rush Lake to the north.

The alluvial basin fill consists of interbedded gravel, sand and clay. The clay layers are sufficiently continuous to isolate the granular layers into confined aquifers. Although no flowing wells remain today, Thomas and Taylor[59] in 1939 found flowing wells in an area of more than 50 square miles. Transmissivities measured from pump tests range from 2,500 to 52,000 ft^2/d, and hydraulic conductivities range from 13 to 250^2 ft/d. The high transmissivities associated with the Coal Creek alluvial fan decline to the north, west and south toward the distal parts of the fan. High transmissivities are also reported south of Quichapah Lake where alluvium is derived from tertiary volcanic rocks, and near and north of Rush Lake where volcanic rocks are interbedded with the alluvium.

Some water has been found in, and produced from, consolidated rocks in the basin, primarily the Navajo Sandstone and some of the igneous rock units. To date, this source has not received much exploration. In 1980 Cedar City explored for groundwater in the Navajo sandstone adjacent to Coal Creek in Cedar Canyon[43] and found a productive well with water of good quality. Because of low production, the Red Hill well has not been used.

Water Rights - When the Utah groundwater law was passed in 1935, Cedar Valley was one of the areas of concern because of declining water levels. The groundwater in the valley was considered to be fully appropriated, and the state engineer approved no further applications for drilling additional irrigation wells pending an investigation.[60] Upon completion of studies in 1940, the central part of the valley was closed to new appropriation. But appropriations were granted in outlying areas such as Enoch, Quichapah and Hamilton's Fort. The entire sub-basin was closed in 1966.

Recharge - Most of the recharge to the unconsolidated deposits is by infiltration from streambeds on the gravelly upper portions of their alluvial fans. Coal Creek is the primary contributor to the Cedar Valley groundwater basin. Surplus undiverted flow in Coal Creek continues to recharge the groundwater system, but as continuing urbanization has crowded the channel, progressively less channel and alluvial fan area has been available for flood flows to spread out and infiltrate. More flood flows are now channeled out into the valley where less favorable recharge areas exist. Average annual recharge may therefore now be somewhat less than the 40,000 acre-feet estimated in 1974.[2] Some recharge is derived from the infiltration of precipitation and excess irrigation, which may also be decreased by urbanization.

Discharge - The annual discharge from the Cedar Valley groundwater basin was estimated in 1974 to be about 43,500 acre-feet. Most of this is discharged from pumped wells, which in 1974 produced 42,300 acre-feet of water. At the present time, pumpage has decreased to 34,000 acre-feet per year from 1991 to 1993(Table 19-2). Annual pumpage responded to surplus and drought in the 1980s as shown in Figure 19-5.

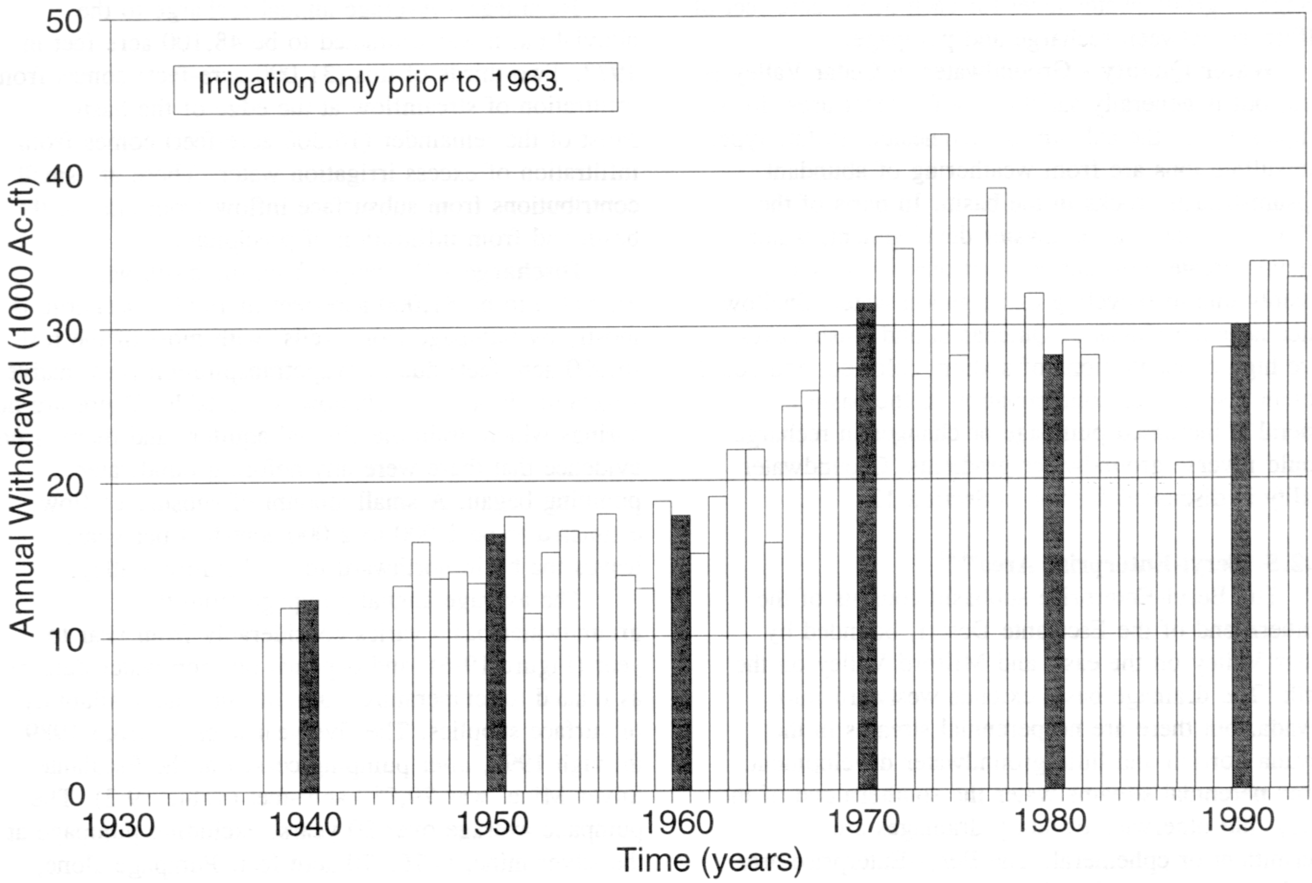
Discharge by evapotranspiration from phreatophytes in the valley bottoms and the playas of Quichapah and Rush lakes was estimated in 1978 to be 2,000 acre-feet, and probably remains about the same. An estimated 500 acre-feet was estimated to flow in the subsurface westward from Cedar Valley to the Beryl-Enterprise Valley via Iron Springs Gap.[59] Although Barnett and Mayo[1] show 1,500 acre-feet per year leaving the basin as subsurface flow to the Virgin River basin to the south, later USGS work[2] found no evidence for it.

Storage - Total volume of water in storage in the alluvial aquifer is estimated to be 20 million acre-feet. An estimated 20 percent or 4 million acre-feet is recoverable. There may be some water in the bedrock aquifers as well, but these reserves have not been explored. The recoverable reserves are large in comparison to the annual discharge, giving the Cedar Valley groundwater reservoir the capacity for substantial holdover storage to buffer wet and dry periods.

Change in Storage - The 30-year change map[5] shows relatively little change in water level in the Cedar Valley from 1963 to 1993. Declines greater than 10 feet are confined to the area west of Quichapah Lake. This indicates that long-term recharge and discharge are more or less in balance in most of the valley. The basinwide decline in water levels which generated concern in the 1960s[5] appears to have ceased.

On a shorter time scale, however, water levels on the Coal Creek alluvial fan have risen and fallen by more than 20 feet showing that the alluvial basin is performing as a storage reservoir on the decade time scale. Barnett and Mayo[5] found a linear relationship between average annual water level change in eight monitoring wells and the difference between the discharge of Coal Creek and annual groundwater

Figure 19-5
CEDAR VALLEY GROUNDWATER PUMPAGE



pumpage, thus showing the direct and immediate response of groundwater to pumping and recharge by Coal Creek. As calculated in 1966, there is a one-foot change in groundwater level for each 5,600 acre-feet of difference between recharge and pumpage.

Water Quality - Groundwater in Cedar Valley is hard, but is generally satisfactory for most uses. Most samples are of the calcium or magnesium sulfate type. The sulfate ions are from weathering of abundant gypsum-bearing rocks in the basin. In parts of the valley with heavy groundwater development, water contains greater concentration of dissolved solids, possibly due to recycling of irrigation water. Shallow water near the playas of Quichapah and Rush Lakes have high concentrations of sodium chloride, and could present a source of contamination to the basin in general if increased pumpage or changes in recharge should reverse groundwater gradients. Groundwater quality is discussed further in Section 12.

19.2.5 Beryl-Enterprise Area[44,47]

The Beryl-Enterprise subbasin consists of the southern end of the Escalante Desert, bounded by Cedar Valley on the east, and Milford Valley on the north. The drainage basin extends westward into Nevada, but there are no perennial streams in the Nevada portion and little groundwater development. Three perennial streams water the southern end of the valley, but otherwise tributary drainages are intermittent or ephemeral. The Beryl-Enterprise area has the least potential recharge in relation to the groundwater in storage of any of the five groundwater reservoirs in the Cedar/Beaver Basin. Cedar City Valley probably contributed to the Escalante Valley during wetter climates in the geologic past through Iron Springs gap. Presently, the flow of Pinto Creek is augmented by a transbasin diversion from the Santa Clara River. Flood flows in excess of those needed for irrigation run into the basin for groundwater recharge.

The Beryl-Enterprise area is a structural basin, partly fault-bounded, containing at least 1,000 feet of unconsolidated alluvial fill consisting of interbedded layers of sand, gravel and clay. Northwest of Enterprise, water is also produced from layered volcanic rock which is permeable and appears connected to the alluvial aquifer. The water-bearing deposits are lenticular in nature, with greater permeability in the horizontal than vertical direction, and becoming finer toward the center of the basin. Pump tests indicate that in a time frame of months or longer, the entire basin can be treated as a single aquifer.

Values of transmissivity calculated from pump tests range from 200 to 120,000 ft^2/d. The highest values are in the area between Enterprise and Beryl Junction.

Recharge - Average annual recharge to the alluvial basin was estimated to be 48,100 acre-feet in 1977. Two-thirds of this (31,000 acre-feet) comes from infiltration of streamflow at the edge of the basin. Most of the remainder (16,300 acre-feet) comes from infiltration of excess irrigation water. There are small contributions from subsurface inflow from outside the basin and from infiltration of precipitation.

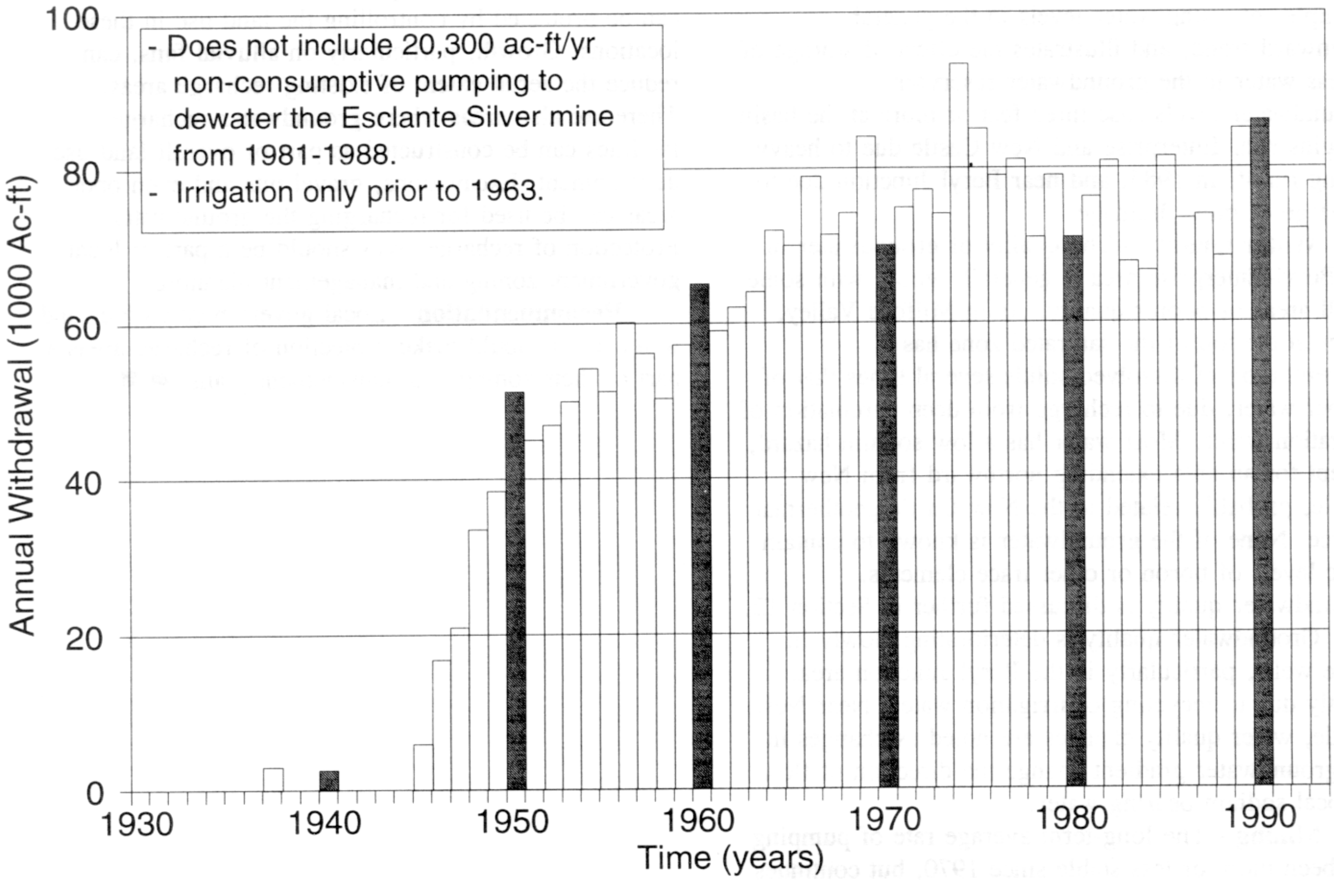
Discharge - Discharge from the basin was estimated to be 81,000 acre-feet in 1977. Discharge is mostly by pumpage from wells, with most of the rest (6,000 acre-feet) due to evapotranspiration from native vegetation in areas of shallow water table. There are no springs which drain the alluvial aquifer, and there is no evidence that there were any before groundwater pumping began. A small amount of subsurface flow, estimated to be 1,000 to 2,000 acre-feet per year, leaves the basin northward to the Milford Valley.

The average annual pumpage from the groundwater basin varies considerably from year to year (Figure 19-6), and depends on crop water demand as related to temperature, rainfall, and the availability of surface supplies. The five-year average from 1989 through 1993, after pumping ceased at the Escalante Silver Mine, was 79,880 acre-feet (Table 19-2). The pumpage average over 30 years, excluding pumpage at the silver mine, is 76,470 acre-feet. Pumpage alone, exclusive of natural basin discharges, has exceeded the average recharge every year since 1950.

Storage - The total volume of water in storage is estimated to be 72 million acre-feet. The volume of water which could be produced by dewatering the upper 200 feet of saturated basin fill as it existed in 1978 is estimated to be 16 million acre-feet of recoverable reserves (Table 19-1).

Change in Storage - Groundwater withdrawals since 1937 have greatly modified the groundwater regime in the south-central third of the area. Groundwater levels have declined by as much as 70 feet in the area between Enterprise and Beryl Junction, creating an artificial depression in the water table, and reversing the natural gradient. Change maps for all periods show decreasing water levels in most of the area.[18] The five-year change map, March 1988 to March 1993,[9] shows declines throughout the basin except for the alluvial apron of the Wah Wah Mountains between Zane and Lund. The 30-year change map shows the long-term decline in the

Figure 19-6
BERYL-ENTERPRISE GROUNDWATER PUMPAGE



southern end of the basin between Enterprise and Beryl exceeding 30 feet over much of the area. The change map for March 1983 to March 1984[18] is one of the few examples of rising water levels in the general downward trend, and illustrates the effect of storage of excess water in the groundwater reservoir. Groundwater levels rose three feet or more at the basin margins near Enterprise and New Castle due to heavy spring runoff in 1983, and near Beryl Junction due to recharge of mine drainage.

Water Quality - The quality of groundwater in the Beryl-Enterprise area is generally good, with some small areas of poorer quality. As in Milford Valley, water at the top of the saturated zone has a concentration of dissolved solids several times that of deeper water, due to recharge from deep percolation of irrigation water. Most water has a low sodium hazard, except for an area extending northward from New Castle, probably related to the New Castle geothermal source. None of the groundwater is known to contain toxic levels of boron or other trace elements. Groundwater quality is discussed further in Section 12.

Groundwater quality is deteriorating slowly in some wells, particularly in the Beryl Junction area, mostly due to recycling of irrigation water. Near New Castle, water quality changes are noted as changes in the groundwater gradient change the direction of flow of local sodium-bearing water.

Mining - The long-term average rate of pumping has been more or less stable since 1970, but continues to exceed estimates of recharge. The continued decline in water levels shows that overdraft is taking place. The state engineer expressed concern over groundwater mining when pumpage in the Escalante Valley increased rapidly from 1945 to 1953.[58] The water table in the pumping district is declining at a rate of less than two feet a year, so that the energy requirement for lifting the water is increasing rather slowly.

19.3 Policy Issues and Recommendations

The only issue discusses the need to preserve groundwater recharge areas.

19.3.1 Groundwater Recharge Areas

Issue - Groundwater recharge areas are susceptible to pollution from man's activities and they need to be preserved.

Discussion - Recharge areas are environmentally sensitive and will become more susceptible to pollution as man's activities increase. Pollution spills in the recharge areas as well as in streams or ephemeral drainages have the potential to contaminate the groundwater reservoirs. Pollution can also come from improperly located land fills, high use recreation areas and improper use of rangeland areas. Recharge areas can be protected by controlling the land use in these locations. Growth, particularly on alluvial fans, can reduce the aerial extent of existing recharge areas. There are also areas where groundwater recharge facilities can be constructed as part of overall land use development. Excavations, gravel pits and even open areas can be used for recharging the groundwater. Protection of recharge areas should be a part of local government zoning and management planning.

Recommendation - Local government entities and water users should make protection of recharge areas a part of their zoning and management plans. ■ ■